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ORIGINAL ARTICLE

A foundation for the study of behavior change support systems

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Abstract The emerging ambient persuasive technology looks very promising for many areas of personal and ubiquitous computing. Persuasive applications aim at changing human attitudes or behavior through the power of software designs. This theory-creating article suggests the concept of a behavior change support system (BCSS), whether web-based, mobile, ubiquitous, or more traditional information system to be treated as the core of research into persuasion, influence, nudge, and coercion. This article provides a foundation for studying BCSSs, in which the key constructs are the O/C matrix and the PSD model. It will (1) introduce the archetypes of behavior change via BCSSs, (2) describe the design process for building persuasive BCSSs, and (3) exemplify research into BCSSs through the domain of health interventions. Recognizing the themes put forward in this article will help leverage the full potential of computing for producing behavioral changes.

Keywords Behavior change support systems · Socio-technical system · Persuasive technology · Behavioral outcomes · Psychological outcomes · Behavioral change

1 Introduction

The emergence of social web and mobile applications to create, access, and share information in new ways has opened up opportunities for also developing new kinds of information systems for influencing users. For instance, one of the most prominent areas for future healthcare improvement is the role of the web in fostering improved health and healthier lifestyles [1]. Researchers have reported positive results in areas such as the management of smoking cessation, hazardous drinking, obesity, diabetes, asthma, tinnitus, stress, anxiety and depression, complicated grief, and insomnia [2]. Other application areas range from persuading users to adopt greener energy behaviors [3] to helping them to stick into proper exercise behaviors [4].

The contemporary and future web will keep opening up a myriad of opportunities for building various kinds of software applications targeted for behavioral change. For this reason, both software developers and the general audience should be aware of the various ways of and the approaches to how people may be, are being, and will be influenced through the information technology designs [5]. In more general, computer science as a field has the responsibility of educating the general audience about the pros and cons of people's behaviors being influenced by information systems, whereas web and other software developers must realize that they exercise enormous power over the users because their designs always influence them in one way or another, whether they intend them to or not.

Scientific research urges for proper theoretical frameworks. Theories related to user attitudes and behaviors are many (e.g., see [6, 7]). However, there is much less attitude/behavior *change-specific* theories; those that do exist include the Self-Efficacy Theory [8], the Social Cognitive Theory [9], and Elaboration Likelihood Model [10]. All of these provide a solid theoretical starting point to carry out research on behavioral changes. Yet, what these theories and therefore many of contemporary studies lack for are descriptions of the software systems in terms of their

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structure, content, and functionality, and in many cases even about their intent [11–14]. We suggest here that in addition to rigor theoretical background and proper methods for measuring the actual behavioral changes, two important steps (in between theory and measurement) must be taken, namely analysis of the intent and analysis of the persuasive potential of the system.

This article is conceptual and theory-creating by its nature. It will suggest two important prerequisites before actually being able to measure and demonstrate a behavior change being caused by an IT artifact. The article is structured as follows: Sect. 2 will describe theories related to behavior change. Section 3 will define and discuss the concept of a behavior change support system (BCSS) as a key construct for research into persuasion, influence, nudge, and coercion, suggesting the O/C matrix as a means for analyzing the intent of a BCSS. Section 4 will position persuasion as the central approach for achieving behavior change via BCSS, suggesting the PSD model as a means for analyzing the persuasive potential of the system. Section 5 will exemplify research into BCSS through the domain of health interventions. Section 6 will discuss the implications and future research directions of the suggested approach. In general, this article lays ground for the new frontier of research on BCSSs.

2 Theoretical background

The study of users' attitudes and behavior has a long history in computer science [15]. Prominent theories related to user attitudes and behaviors include, for instance, the Theory of Reasoned Action [6] and the Theory of Planned Behavior [7]. Lessons have been drawn especially from social psychology and cognitive psychology, and even some original computer science theories have been developed, such as the Technology Acceptance Model [16] and the Unified Theory of Use and Acceptance of Technology [17]. These theories are useful for understanding behavioral intentions and control related to information systems and their use, and some of them are relatively well-known among computer scientists. Besides these attitude and behavior-related theories, there are some theories that specifically discuss the change of attitudes or behaviors, such as the Self-Efficacy Theory [8], the Social Cognitive Theory [9], the Elaboration Likelihood Model [10], the

Table 1 Behavior change–related theories

Theory of reasoned action	Individual behavior is determined by behavioral intentions, i.e., an individual's attitude toward the behavior and subjective norms about the behavior [6]
Theory of planned behavior	Individual's perception of the ease with which the behavior can be performed, i.e., behavioral control influences individual's behaviors [7]
Technology acceptance model	Perceived usefulness and perceived ease of use determine an individual's intention to use a system, which leads into actual system use, perceived ease of use impacts perceived usefulness, assumes that actors are free to act without limitations when they just have an intention to act, based on theory of reasoned action [16]
Unified theory of acceptance and use of technology	Performance expectancy, effort expectancy, social influence, and facilitating conditions determine the usage intention and usage behavior, whereas gender, age, experience, and voluntariness of use moderate this impact; extended from technology acceptance model [17]
Self-efficacy theory	Individuals who perceive themselves as capable of taking action also do take action; strengthening the sense of efficacy happens through vicarious experiences, social models, social persuasion, and reducing people's stress reactions and altering their negative emotional proclivities and misinterpretations of their physical states [8, 68]
Social cognitive theory	Observing others performing a behavior influences the perceptions of individual's own ability to perform the behavior, i.e., self-efficacy, and the perceived expected outcomes [9]
Elaboration likelihood model	Central and peripheral routes are key routes for persuasion; central route is used when information processing is based upon critical thinking; peripheral route is based on rules of thumb; change via central route is more enduring, resistant and predictive of behavior [10]
Cognitive dissonance theory	Individuals seek consistency among their cognitions such as beliefs and opinions; inconsistency between attitudes an behaviors creates dissonance that needs to be eliminated [18]
Goal setting theory	Goals affect performance through directing attention and effort, energizing, persistence, and by leading to arousal and/or use of task-relevant knowledge and strategies; the highest goals produce the highest levels of effort and performance; specific, difficult goals consistently lead to higher performance than urging people to do their best; when goals are self-set, people with high self-efficacy set higher goals than people with lower self-efficacy; people with high self-efficacy are more committed to the assigned goals and to responding more positively to negative feedback [19]
Computer self-efficacy	Computer self-efficacy means individual's judgment of one's capabilities to use computers for both task performance and computer performance; anxiety, innovativeness, task characteristics, prior performance, and perceived effort play a role, based on self-efficacy theory [20]

Cognitive Dissonance Theory [18], and the Goal Setting Theory [19]; even a few extensions of these theories into the computer science field do exist such as the Computer Self-Efficacy [20]. These change-specific theories are not very well-known among computer science researchers, however. For a summary of behavior change–related theories, see Table 1.

There are also specific theoretical models within application domains; for instance, models that have stemmed from the healthcare field and which have received large attention in health behavior change include the Health Belief Model [21, 22] and the Transtheoretical Model [23, 24]. Some world-renowned scholars, such as Fishbein [25] and Bandura [26], have recently also been working in the area. For instance, Fishbein's [25] integrative model combines variables derived from the Health Belief Model, the Theory of Reasoned Action, and Social Cognitive Theory. According to this model, an individual is more likely to engage in a target health behavior if one's intention to perform is strong, one has the skills and abilities to perform it, and one does not encounter barriers to engaging in the behavior. Those who intend to perform a specific behavior but are unable to do so are very different from those who have no intention and lack motivation. Theoretical frameworks specifically developed for helping to understand software users' health behavior changes have also been suggested, such as the eHealth Behavior Management Model [27].

All of these behavior change–related theories and models, no matter whether they are health-specific, software user focused or more general ones, however, lack in their understanding and descriptive power for the potential uses and benefits and in particular for the information system characteristics. For this reason, sharper conceptual-theoretical means for carrying out research on information systems focused on behavioral change are needed.

3 Analysis of the intended outcome/change

Even if the web and other information technologies are often considered as just tools to accomplish goals, they are actually never neutral; rather, they are "always on" [5]. This means that people are constantly being persuaded in a similar manner to how teachers persuade students in schools, and there is nothing bad in this in itself, of course. To put it simply, information technology always influences people's attitudes and behaviors in one way or another. In some cases, the influence may even be an unintentional side effect of the design. Thus, software designers but also the general audience should be well aware of the various ways and approaches how people may be, are being, and will be influenced through IT design.

There is a plethora of applications that can be developed with the purpose of behavioral change.[1] For these reasons, it is important to define and adopt into use the concept of a behavior change support system. A BCSS is defined here as follows:

A behavior change support system (BCSS) is a socio-technical information system with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception.

In this article, three potential, successful voluntary outcomes are the formation, alteration or reinforcement of attitudes, behaviors, or complying. Based on the intended outcomes and the types of change, a framework for helping design and research, the O/C matrix, is suggested here, see Table 2. A forming outcome (*F-Outcome*) means the formulation of a pattern for a situation where one did not exist beforehand, for example, abstaining from substance abuse. An altering outcome (*A-Outcome*) means changes in a person's response to an issue, for example, increasing the level of exercise, decreasing the amount of drinking, or stopping smoking. An increase or decrease on a behavior can be related to frequency, intensity, or duration of the behavior [28]. Stopping a behavior in practice leads often into a situation in which also forming a new behavior (*F-Outcome*) is initiated. A reinforcing outcome (*R-Outcome*) means the reinforcement of current attitudes or behaviors, making them more resistant to change. Thus, *R-Outcome* should be treated as change as well, even if its magnitude may be relatively small or it would not suggest a transformation from one position to another position. In many cases, a *F-Outcome* may have a higher likelihood of success than communication that aims at *A-Outcome*, whereas reinforced beliefs and behavior (*R-Outcome*) become the most resistant ones as time goes by [29]. Naturally, users' motivational level and goal setting [19] play a big role in trying to achieve any of the *F-*, *A-*, or *R-Outcomes*.

In the abovementioned definition of the BCSS, we divide changes into three categories, namely a change in an act of complying, a behavior change, or an attitude change.[2] Respectively, these archetypes of a behavioral change may be called *C-*, *B-*, and *A-Change*, in ascending order of difficulty.

With a *C-Change*, the goal of the behavioral change is simply to make sure that the end-user complies with the

[1] It should be noted that even if we speak about behavioral changes, we do not posit a behaviorist or any mechanistic psychological view towards human beings. End-users may use these applications to support achieving their goals, maintaining a constructivist view (cf., the field of education) towards human behavior.

[2] For the sake of simplicity, we use the term "behavior" change rather than "behavioral" change even if the BCSS covers all three behavioral change types.

Table 2 Outcome/change design matrix

	C-Change	*B-Change*	*A-Change*
F-Outcome	Forming an act of complying (F/C)	Forming a behavior (F/B)	Forming an attitude (F/A)
A-Outcome	Altering an act of complying (A/C)	Altering a behavior (A/B)	Altering an attitude (A/A)
R-Outcome	Reinforcing an act of complying (R/C)	Reinforcing a behavior (R/B)	Reinforcing an attitude (R/A)

requests of the system. For instance, the goal of a healthcare application may be to guarantee that its users take their daily blood pressure medication. The users may or may not have the proper motivation for doing so, but, nevertheless, the key in this approach is to provide triggers for the user to take action and to comply with the requests of the application. Yet, first achieving a *C-Change* may help to achieve a *B-Change* later. It should also be noted that a myriad of software applications that have been created for purposes other than a behavioral change per se utilize, in the micro scale, the same design principles and techniques as systems supporting *C-Change*. In other words, they "nudge" the user through user interface, social, or other cues.

The goal of systems supporting a *B-Change* is to elicit a more enduring change than simple compliance once or a few times. Naturally, a one-time behavior change may be achieved more easily, whereas long-term behavior change (not to even speak about a permanent behavior change) is much more difficult to achieve. Schedule for performing a desired behavior also plays a role in behavior change, especially with *B-Change*. One-time behavior may lead to an ongoing obligation or cost, a behavior may be exercised for a period of time, or a behavior may be repeated on predictable schedule [28].

The goal of systems supporting an *A-Change* is to influence the end-users' attitudes rather than behavior only. An attitude change that directs behavior may be the most difficult type of change to achieve but we maintain that change-in-full occurs only when attitude change takes place and that a sustainable *B-Change* happens only through an *A-Change*. In some cases, behavior change support systems should aim bolstering both an *A-Change* and a *B-Change* simultaneously. This is particularly important in areas such as providing support for overcoming addictive behaviors, where users in spite of high motivation and proper attitudes may lack the skills to put their knowledge and attitudes into practice (a *B-Change* is needed), but at the same time, their self-efficacy may need further strengthening (an *A-Change* is needed).[3]

[3] Tørning and Oinas-Kukkonen [30] report some interesting findings about the current state of research on BCSSs. For instance, thus far there has been much more research on *C-* and *B-Change* than on *A-Change*; only about 16 % of studies in their analysis regarding the different types of change addressed *A-Change*.

By definition, different goals and often also different strategies will be needed for applications supporting *A-*, *B-*, or *C-Changes* as well as for targeting at *F-*, *A-*, and *R-Outcomes*. When researching or developing a BCSS, it should be carefully considered which of these nine outcome/change cells an application is aimed at in order to be better equipped to pinpoint the research results and/or to direct design efforts. The context for change may be remarkably different between the different cells in the matrix. For instance, helping a schoolchild to adopt a healthy lifestyle by deciding not to start smoking (F/B), encouraging a teenager to continue to stay away from smoking despite of potential peer pressure (R/B), and motivating someone that currently smokes to stop smoking (A/B) would require in most cases very different approaches. Yet, the description of the intended outcome/change is sometimes lacking, not only from applications, but even from scientific articles specifically focusing on interventions for behavioral change. Furthermore, how to move from one cell to another seems to be a neglected area in BCSS research.

In overall, what distinguishes research into BCSSs from research into other information systems is that BCSSs are inherently transformative, deliberately attempting to cause a cognitive and/or an emotional change in the mental state of a user to transform the user's current state into another planned state and to cause a corresponding change in the user's behaviors. In implementing these systems, many kinds of issues have to be taken into account. Some of the issues are technical, but many of them are user-related, social, and in some situations, they may also relate to organizations, cultures, or society; they may relate to the quality and content of information, personal goals set by the end-users, and social environments, among other issues. The development of BCSSs cannot be narrowed down to being just a user interface issue either. Indeed, a variety of topics beyond human–computer interaction and computer-mediated communication, such as approaches, methodologies, processes, and tools to develop such systems and ways for studying the organizational, social, and end-user impacts of them need attention. Technologically, the research may relate to socio-technical platforms, systems, services or applications, or the software features in them, developed for the purpose of achieving behavior change; these all denote different approaches. In many

cases, the BCSSs must be available 24/7, they have to address global and cultural issues with a multitude of standards, habits, and beliefs, and they have to be adaptable into a variety of business models.

4 Analysis of the persuasive potential

Many forms of attempted influence do exist, including deception and coercion as well as monetary inducements. These other means may be very effective vehicles for producing behavioral changes, but the voluntary nature of behavior change *support* systems excludes, by definition, deception and coercion (cf. [31]). For instance, pop-up windows that always lead to the same outcome (e.g., downloading a file) whether you choose "ok" or "cancel" can be considered both deceptive and coercive. An ideal BCSS *persuades* its users to adopt the target behavior. The role of inducements, that is, exchanges of money, goods, or services for actions by the person being influenced, is a more complicated issue. Yet, in its purest form, persuasion excludes at least monetary inducements; persuasion relies on the power of verbal and non-verbal symbols and allows people's voluntary participation in the persuasion process [32].

Persuasive design and technology has received growing interest among researchers for a little over a decade now (cf. [33]).[4] Fogg's seminal book [36] was the first conceptualization suggested for software designers, stating that information technology may play the role of a tool, a medium, or a social actor for its users, whereas Bogost [37] proposed an approach to developing persuasive games. More recently, elaborate conceptual and design frameworks for on and off-the-web information systems have been suggested, such as the Persuasive Systems Design model [5, 38]. A wide variety of persuasive applications have been developed, such as an easy-to-use password creation mechanism to help create stronger passwords [39], an interactive picture frame for adopting better sitting habits while working at the computer [40], a ubiquitous sensor-based kitchen application for improving home cooking by providing calorie awareness regarding the food ingredients used in the meals prepared [41], and a personal health information system to influence the health behaviors of rural women in undeveloped countries through offering them information for increasing their awareness about menses and maternal health [42]. Recently, one of the major development trends has been the persuasion patterns of social network-based information systems, in particular in conjunction with Facebook [43] and Twitter [44].

Indeed, the key element in voluntary use of a BCSS is persuasion. Thus, behavior change support systems are, in essence, persuasive systems. They may utilize either computer-mediated or computer–human persuasion [45]. Computer-mediated persuasion means that people are persuading others through computers, for example, e-mail, instant messages, or social network systems. Some patterns of interaction similar to social communication may be utilized also in computer–human persuasion, even if the web cannot communicate in the same way as humans do. However, in the case of BCSSs, there always are stakeholders who have the intention of influencing someone's attitudes or behavior, as computers do not have intentions of their own. These stakeholders are those who create or produce BCSSs, those who give access to or distribute them to others, or the very person adopting or using such a system [36]. BCSSs emphasize—but are not limited to—autogenous approaches in which people use information technology to change their own attitudes or behaviors through building upon their own motivation or goal. Beyond being a special case of a persuasive system, a BCSS also has characteristics of its own. A BCSS places more emphasis on the actual outcome than a persuasive system, which, even if its developers were interested in the outcomes as well, in most cases emphasizes more the persuader's intent than measuring the actual outcome. Another special characteristic of BCSSs is that they request a much stronger emphasis on positive user experience and stickiness to motivate users to engage with them regularly over an extended period of time.

The Persuasive Systems Design model [5, 38], or more briefly the PSD, is the state-of-the-art vehicle for designing and evaluating BCSSs [46–52], see Fig. 1. The PSD model defines seven postulates or core issues that are common for all BCSSs. Philosophically and as already stated above, information technology is never neutral but rather it always influences its user(s) in one way or another (P1). Moreover, building BCSSs requires insight from software and information systems design as well as from psychology. Lessons learned from psychology include that (P2) people like their views about the world to be organized and consistent, (P3) persuasion is often incremental, and (P4) the direct and indirect routes are key persuasion strategies.[5] Important software design requirements to be always kept in mind when developing BCSSs are that: (P5) behavior change support systems should be both useful and easy to

[4] Persuasive technology can be described as an interdisciplinary field of research, whereas a BCSS is an object of study within the field. Affective computing [34] may be recognized as a sister-field of persuasive technology, or perhaps from the persuasive viewpoint as a sub-field of it, which more directly focuses on the emotions systems evoke. Sharp criticism of persuasive technology has been posed by Atkinson [35].

[5] Psychological theories tend to differ between each other in their views to and emphasis of P2, P3 and P4.

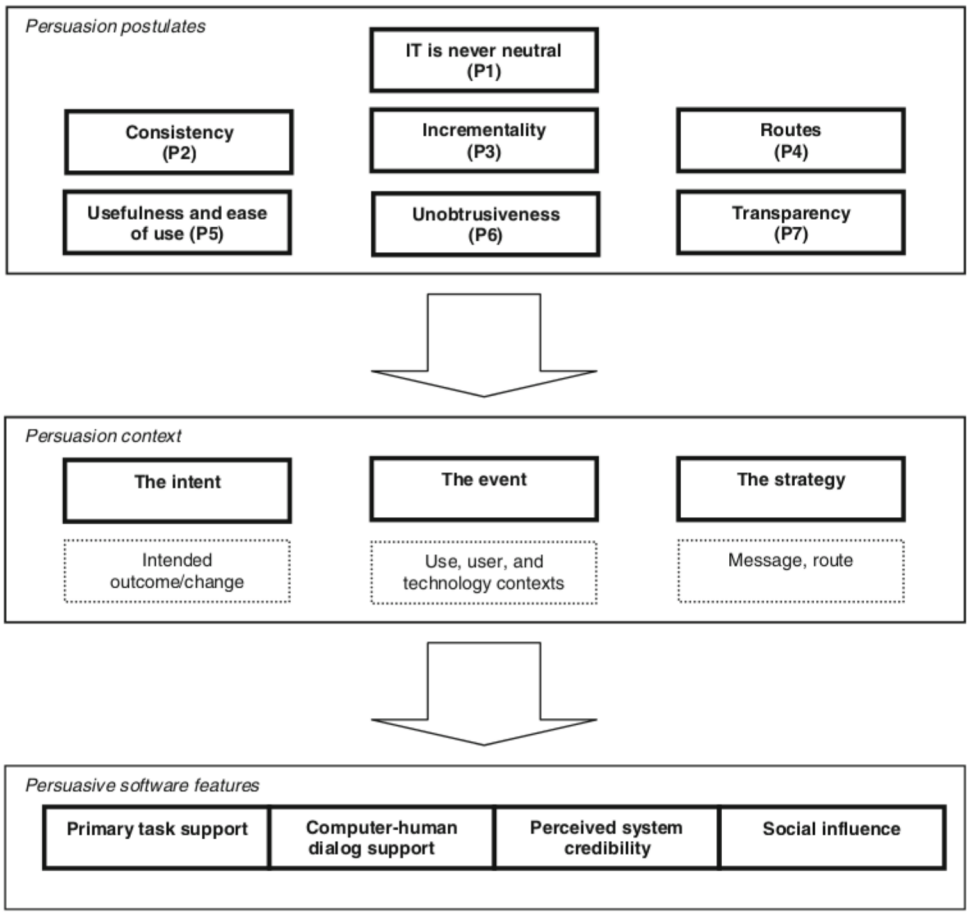

Fig. 1 The persuasive systems design process (modified from [5])

use, (P6) persuasion through behavior change support systems must always be unobtrusive to a user's primary tasks, and (P7) persuasion through behavior change support systems should always be transparent. Quite understandably, if a system is useless or difficult to use, or it is not well-mapped with a user's first and foremost interests and needs, it is unlikely that it could be very persuasive. The transparency requirement emphasizes the need for revealing the designer bias behind a BCSS.

According to the PSD model, the next step needed after obtaining a deeper understanding of persuasion in general is a careful analysis of the persuasion context (the intent, event, and strategy of persuasion) to discern opportune and/or inopportune moments for delivering the message(s). This is where the intended outcome/change is analyzed via the O/C matrix; in a similar manner, the message and the route that will be used to deliver the message, the user and use situation modeling, and many technological issues must be resolved.

The PSD model also defines a wide range of software features[6] for BCSSs and describes them under four categories, namely primary task support, computer–human dialog support, perceived system credibility, and social influence, see Fig. 2. The design principles of the primary task category, for example, tailoring, tunneling, and self-monitoring, focus on supporting the carrying out of the user's primary activities; design principles related to computer–human dialog, for example, verbal praise, timely suggestions, virtual rewards, and real-time reminders, aim at easing the achievement of the goal(s) set for using the BCSS; the perceived system credibility design principles relate to how to design a system so that it is more believable and thereby more persuasive, for example, by showing expertise or referring to authority and endorsements; and the design principles in the social influence category describe how to design the system so that it motivates users by leveraging social behaviors, for example, via social learning, comparison, and facilitation. The PSD model does not, however, put forward a claim that all possible software features should always be implemented into a BCSS. It should be noted that in some cases, increased elaboration may lead into decreased overall persuasiveness (cf. [10]). It is also important to note that many of the aspects in developing BCSSs are general software design

[6] Many of these persuasive features originate from Fogg [36].

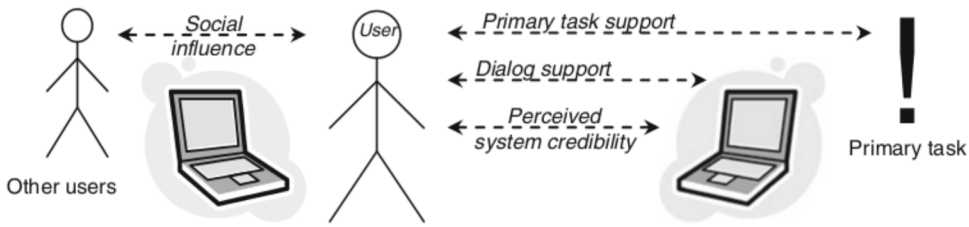

Fig. 2 Persuasive software feature categories in BCSSs

and content creation issues rather than specific to BCSSs only. These include, for instance, lack of errors, high information quality, attractiveness, responsiveness, ease of access, and high overall usability.

The applicability of the PSD model is wide. The model can be used in a variety of settings ranging from evaluating software specifications in the early stages of systems development [53] to studying full-fledged commercial applications [54] to analyzing research literature in a given problem domain [14, 55]. The PSD model is a highly useful tool for researchers and designers, but of course it can not guarantee the success of any BCSS. For examples of studies explicitly using the PSD model, see Table 3.

5 Example: health BCSS

The research into healthcare information and management systems thus far has mostly focused on electronic medical records and health information libraries with less attention to tools for patients' behavioral change ([56]; for the latter, see for example, [57, 58]), and yet one of the most prominent areas for future healthcare improvement has been suggested to be the role of information systems in fostering improved health and healthier lifestyles [1]. Current health behavior change support systems still are typically behavioral treatments operationalized and transformed for web delivery with the goal of symptom improvement [59], but they can also be delivered via SMS, social networking systems, or by other state-of-art technological means. In fact, there is already a plethora of health interventions available via mobile devices. Health BCSSs have been reported to produce positive results in areas such as management of smoking cessation, hazardous drinking, obesity, diabetes, asthma, tinnitus, stress, anxiety and depression, complicated grief, and insomnia [2]. Naturally, the research has not found these interventions always to play the biggest role in the change process, but nevertheless, the majority of the published works have found improved knowledge and positive psychological, behavioral, or clinical outcomes [60]. At the same time, room for significant improvements still exists. For instance, 80 % of the smoking cessation sites failed to cover one or more key components of recommended cessation treatment guidelines and the true utilization of the web's most potential features was generally ignored [61]; in many cases, these software applications also made very low utilization of health behavior change theories [62].

In medicine and psychology, it is randomized controlled trials (RCT) that are appraised and that receive most of the attention. The elevated position of RCTs being "the king" is only natural, because via RCTs, it is possible to actually measure and demonstrate a change in a behavior. Previously, there were relatively few RCTs studying health behavior change support systems. However, in the last decade, things have changed and more and more randomized controlled trials about health BCSSs have been published. Portnoy et al. [63] conducted a meta-analysis of RCTs on efficacy, improved antecedents of health behavior, and general health maintenance from studies carried out between 1988 and 2007. They discovered that several characteristics moderated the improved psychological (knowledge, attitudes, and intentions) and behavioral outcomes (e.g., nutrition, substance use). Improved results were achieved at the first milestone, that is, at first post-treatment assessment. The researchers suggested that longer research periods would be needed in further research. From the 75 RCTs Portnoy et al. [63] studied, 73 % used at least one theory, and 36 % used more than one theory. In terms of problem domain, 37 % of the studies were related to overweight/obesity and 23 % on alcohol and/or drugs. The data were often relatively biased, since in 59 % of the studies, the participants came from a community/clinical setting, and in 38 %, they were from a school/university setting. A median RCT was found to provide three intervention sessions of 21 min each (with a single theory), 11 intervention sessions of 45 min each (when multiple theories were used), or 42 intervention sessions of 6 min each (when electronic peer support was used—however, there were only two of these kinds of systems in the data). According to the study, 65 % of the health BCSSs were tailored. Out of these, 18 % were tailored toward a group, 88 % included a motivational component, and 89 % included skill training. They found evidence of successful support on six widely varying behaviors, including substance use, which is often resistant to change even with therapist-facilitated interventions. Their explanation for this surprisingly positive result is that

Table 3 Examples of BCSS studies related to the PSD model

Davis [69]	Studied the ethical implications of persuasive systems in relation to participatory design methods and utilized the PSD to introduce persuasive features for the participants in their "inspiration card workshops"
Harjumaa et al. [4]	Qualitative study in exercise domain by using heart-rate monitors; 12 participants for a period of 3 months; the system was found to incorporate ten distinct persuasive features; some features influenced most users whereas some had effect only on some of them; the most motivating features were found to be the weekly goals, tracking performance during and after exercising and on a weekly basis, and the adoption of a social role; short-term verbal system feedback via praise and rewards appeared to be powerful in some specific cases
Kelders et al. [55]	Systematic review of the persuasive features in BCSSs for weight control and weight loss; findings suggest that with web-based interventions, most attention thus far has been given to the primary task support, whereas dialog support and social support appear to be neglected; suggest that persuasive systems can increase adherence and lower attrition rates in e-health studies
Lehto and Oinas-Kukkonen [11]	Qualitative evaluation of the persuasiveness of six web-based alcohol interventions; despite of the intended *B-Change*, the systems were not found to be very persuasive; they provided relatively poor primary task support (surprisingly little use of tailoring); successful in trustworthiness, expertise, and surface credibility; notable differences in online social influence; the systems seem to be targeted for too broad an audience
Lehto and Oinas-Kukkonen [70]	Qualitative evaluation of persuasive features on weight-loss websites; the evaluated systems were found to provide relatively good primary task support and strong social support; weaknesses in both dialog and credibility support; the overall persuasiveness relatively low; improvements suggested
Lehto and Oinas-Kukkonen [14]	Systematic review of web-based interventions for substance use; randomized controlled trials published during 2004–2009; interpretive approach for persuasive features; primary task support was reported relatively widely in the reviewed studies (reduction, self-monitoring, simulation, and personalization being the most used features); leveraging reminders was the most common way to enhance the user-system dialog; credibility support was at a relatively high level; the prevalence of social support was encouraging
Räisänen et al. [53]	Applied the PSD model for evaluating the persuasiveness of software design specifications for a internet tablet under development; the model was found to fit well for evaluating design specifications; suggests also that practitioners with no theoretical background on the PSD can apply the model to increase the persuasiveness of the systems they design; exemplifies how to use the PSD model in relation with a specific theory; the need for specific heuristics for evaluating persuasive features recognized
Segerståhl et al. [54]	Qualitative field study about situations where persuasive features do not function as expected; weight loss utilized as an problem domain; PSD used to recognize persuasive features; the pitfalls discovered linked with manual logging of eating and exercise behaviors, provision of suggestions and source credibility regarding social facilitation
Stibe et al. [44]	Quantitative survey of Twitter users in Latvia; addressed the incremental persuasion postulate; focused on persuasion patterns in social networks and microblogging; suggests patterns for step-by-step *B-* and *A-changes*
Tørning and Oinas-Kukkonen [30]	Review of research on persuasive systems; most research thus far has been experimental; 84.4 % has addressed *C-* or *B-change*; the most utilized features have been tailoring, tunneling, reduction, and self-monitoring (representing the primary task category), suggestion (for supporting human–computer dialog), surface credibility (in support of perceived system credibility), and social comparison, normative influence, and social learning (relating to social influence); surprisingly, ethical considerations have remained largely unaddressed
Wiafe et al. [71]	Extended the PSD model for helping to select appropriate persuasive techniques depending on the nature of users or use over time; present a model between attitude toward behavior, attitude toward change or maintaining a change, and current behavior; distinguish variable levels in a user's cognitive state
Yetim [72]	Critically uses and evaluates the PSD model, proposing a set of questions for pragmatic, ethical, and moral discourses for the design and use of persuasive systems; based on argumentation research; emphasizes value-sensitive participatory design

health BCSSs may help organize previously latent motivation and behavioral skills.

Portnoy et al. [63] suggest that one of the challenges in health BCSS research is that providing an individual with any active intervention content is likely to lead to some change in the psychological antecedents and/or behavior. Moreover, in many cases, any active comparison condition (including placebo) may decrease the difference between the treatment and control groups. They also found that older participants were less efficacious for increasing knowledge, attitudes, and self-efficacy. This may be a result of the selected sets of participants, which, to a relatively large extent, were student-based. Quite surprisingly, the inclusion of motivational components, such as cost-benefit analysis for a behavior, seemed to weaken the impact of the health BCSS on *A-Change* and social norms. This is a counter-intuitive finding and needs more research. They found no support for the impact of tailoring activities (whether at individual or group level) on the change, which also offers room for further research.

According to Ritterband et al. [59], the web may make a significant difference, particularly in *C-Change*, even if

studying the *C-Change* may also become more problematic via the web because of limited supervision and control. Nevertheless, the web-based health BCSSs may be highly engaging and personalized, and they may, for instance, offer information in the form of quizzes, games, and case reports—something that is a relatively new idea in the field of health information systems. It would be important to assess the impact of these both individually and as a part of a larger whole from multiple viewpoints (e.g., feasibility, usability, and efficacy). According to Ritterband et al. [59], more research on the web's ability to elicit actual behavioral changes, more methodologically rigorous clinical studies, and a theoretical model for behavioral change are still badly needed. These will provide a new platform from which research on health behavior change support systems can be conducted.

One of the greatest challenges for the BCSSs is that physicians generally think that information systems have little relevance to their clinical work with patients. Moreover, most of the research questions tackled in scientific publications so far have focused on problems that are relatively easy to solve or at least which are easily measurable. In future work, more serious problems should be tackled and a more complex view toward the durability of the behavioral change should be adopted. Currently, most of the researchers involved with systems supporting health behavioral change and having their background in the healthcare field seem to be interested in either *C-* or *B-Change*. Most of those computer–human interaction researchers who are involved in the area of behavioral change seem to focus on *C-Change*, too, whereas social psychologists working in the area of health BCSSs constitute the largest single group of researchers who are interested also in *A-Change*. In the future, more research should be devoted to *A-Change* rather than *C-* or *B-Change* only.

Even if Portnoy et al. [63] and others have found evidence for the success of health BCSSs, there is a major drawback in most of the published works so far. The support systems are almost always very poorly described [13, 14]. All too often, no details about the system are provided at all. A major reason for this deficiency is that most of this type of research has been published by physicians and medical experts without consulting the computer scientists. Moreover, many larger health organizations typically prefer to create their own materials, and they are only now beginning to understand that custom web sites that go beyond their pamphlets require significant expertise, effort, and expense [2]. Knowledge delivery does not automatically equal health behavior change. Much more than just the provision of information is needed. Duffett-Leger et al. [64] admit that health-related disciplines have largely overlooked the lessons learned from other scientific disciplines on how best to persuade behavioral change. What is urgently needed is research on the system feature level or on the level of categories of system features rather than on the level of the whole system only.

6 Discussion

Empirical BCSS research provides a unique opportunity for quantifying measures for system success. This requires explicitly stating the aim of the system, how the success was to be measured, and the extent to which the system succeeded in achieving this measure. It has to be explicitly defined what really takes place through the software system to be able to demonstrate to what extent an outcome/change is really due to the system, or a feature or a set of features in it. Thus, sound ways for defining the systems and their intent clearly are needed. Otherwise, it will be difficult or perhaps even impossible to demonstrate the value of any research results from the BCSS and to translate the lessons learned from the results into related problem and application domains. On the theoretical side, even the relatively well-known persuasion techniques need to be adapted or fine-tuned to match computing specificities.

Yet, in the current research, there is a clear tendency of describing the BCSSs at too general a level (e.g., [13, 14]). When describing a BCSS, a clear description of the persuasion context, that is, contexts related to use situation, a user him or herself, and the information technology being utilized, is needed. After all, much of the success or failure of an application can often be attributed to the fluent navigation and smooth interaction arising from the technological platform and infrastructure or overall user experience rather than to the specific design of the system. Relying on *black-box thinking of software systems*—with no actual description of what was implemented and how—is a symptom of a misunderstanding of conducting BCSS research. This black-box thinking of the software systems may even make some of the research results obsolete. The differences between problem domains also are remarkable to the extent that very general claims can be seldom argued for. For instance, in most of the experimental research into persuasive technology, users (often students) are regarded as a homogenous mass; more specific information is often limited to gender and age [30]. Yet, deeper understanding of the user segments [65], or perhaps even individual user profiles [66], is important for designing successful BCSSs. Specific target audiences may request different kinds of software features. Just consider the differences between small schoolchildren, tweens, teens, and young adults in comparison to lumping them all together as students. The

Table 4 Open BCSS research agenda

Theoretical basis	How can we map psychological and behavioral theories within computer and information science frameworks?
	When should a BCSS use a direct and/or indirect persuasion strategy?
	What is the role of goal setting in different kinds of BCSSs? How can changes in the user's goals during the process be supported?
	What are the roles of cognition and emotion in BCSSs?
	What is the relationship between convincing and persuasion in BCSSs?
	What is the difference between persuasiveness and perceived persuasiveness? How should perceived persuasiveness be measured?
	What are the finer differences between problem domains (e.g., reduced energy consumption vs. overcoming addictions or increased exercising vs. weight management)?
Analysis of the intended outcome/ change	What challenges do *A*-, *B*-, and *C-Change* pose for carrying out BCSS research? What are the similarities and differences in measuring C-, *B*-, and *A-Changes*? What are the connections between C-, *B*-, and *A-Change*? How to actually measure C-, *B*-, and *A-Changes*?
	How do the BCSSs developed for C-, *B*-, and *A-Changes* differ from each other? How do the BCSSs developed for *R*-, *A*-, and *F-Outcome*s differ from each other?
Analysis of the persuasive potential	How can we build BCSSs in such a manner that they will be unobtrusive with users' primary tasks?
	How can we conduct experiments in such a manner that it will be really possible to pinpoint a change to have been caused by a BCSS, or even more precisely, by a specific software feature in it?
	Which software features or combinations of software features have the greatest impact in different settings?
	Which modes of interaction are more persuasive than others? How can the fit between these interaction modes and catering for certain types of behaviors be recognized and measured?
	In general, how do different persuasive features relate to each other?
	What are the challenges in the development of persuasive ecosystems/platforms/systems/services/ applications/features?
	What is the difference between developing a BCSS as a software system versus as a software service (e.g., a mash-up)?
	What challenges result from the requirement for a service to be available 24/7?
	How can we cope with it when the technological platform which the BCSS has been built upon changes dramatically between starting and ending the measurement?
Business, ethical, cultural and other considerations	How can we recognize and analyze the unintended side-effects of using a BCSS? What kind of abuses of a BCSS can be recognized and how?
	How and to what extent should the bias behind a BCSS be explicated?
	What are viable business models for BCSSs?
	What are the cultural and gender differences in BCSSs?
	What other research issues (other than ones relating to the user interface) need to be tackled?

message and route for persuasion are also often not described at such a level of detail that it would be possible to determine whether a direct or indirect approach actually has been applied and whether that has played a role in the success or failure of the system. Moreover, it should be clearly defined whether one or multiple arguments were presented and what kinds of arguments were presented. It is the abovementioned O/C matrix, which can help analyze the intent of the BCSS, whereas the PSD model helps in analyzing the persuasiveness of the BCSS. In rigorous BCSS research, these should be used on par with the relevant theories to give meaning for the research results obtained through surveys, studies, experiments, and other research attempts. Indeed, to carry out BCSS research, one should choose (one or more) suitable theories and then analyze the intent of the BCSS and the persuasive potential of the BCSS before proceeding to measuring and explaining the change. Admittedly, space in scientific articles is often too limited to provide very many details about the system itself. For this reason, the actual system descriptions easily become radically shortened or even end-up being cut out from the papers. But those should be included in the articles and/or in their multimedia appendices. Moreover, the field would benefit from a shift in research emphasis from proof of concept approaches into theorizing for BCSS and persuasive systems design. Even if the framework suggested via the PSD model does not define directly the most suitable technologies to be utilized

in each project, it helps to recognize such design- and implementation-related issues that enable to choose viable technological platforms. In similar manner, the power of the O/C matrix is in recognizing key design and research issues rather than providing direct and explicit measures for a project's success.

Quite surprisingly, ethical considerations, in spite of often mentioned, have remained largely unaddressed in BCSS research [30]. Regarding this, many important issues need to be recognized, such as the actual voluntariness for change in using the application and potential ways for abusing the system. There may also be situations where computer-mediated persuasion takes place without the user being aware of it. These "grey areas" should be carefully considered. All too often the empirical and experimental research does not reveal much about the motives behind the system under study. The designer bias should necessarily be revealed much more clearly.

For a list of open research questions to be tackled in future BCSS research, see Table 4. In spite of these many questions, the ultimate question still is, of course, how to measure behavior change through a BCSS. Yes, being able to measure and thus demonstrate the behavior change being caused by an intervening BCSS or in best cases by a specific feature in it is quintessential for determining the success of any of such interventions.

As can be seen from Table 4, many research questions remain to be addressed and multiple research methods and approaches may be applied for studying the behavior change support systems. Even if ample research efforts have already been conducted thus far, we are still in the very early steps of research into BCSS. Observing users and monitoring their social interactions, use of living labs, open innovation and crowdsourcing methods, use of design research methods, study of user experiences, experimenting with emotions and building affective computing prototypes all provide interesting opportunities for research. Eye-tracking and measurements based on heart rate and other physical or bodily functions [67] may help understanding, for example, users' subliminal behaviors, and fMRI (functional magnetic resonance imaging) provides an interesting method and avenue for future research. Indeed, many kinds of research experiments can be done, but in particular behavioral measurements in natural environments would be desirable.

7 Conclusion

In spite of its very rapid development, the emerging area of behavior change support systems is still in its infancy. It is challenging to measure actual behaviors, and even more so changes in behavior that is the goal of these systems. The major weakness in research into BCSSs thus far has been that the information systems, which are the core of the whole phenomena, all too often have been described in such a coarse manner that it has been very difficult to demonstrate what actually caused a change, if any, or to generalize any of the findings. This article has proposed methods for understanding the prerequisites for being able to actually measure these systems. The concept of behavior change support system was suggested as a key construct for research into persuasion, influence, nudge, and coercion. The O/C matrix and the PSD model were suggested as vehicles to better frame research and design activities. The article also suggested that a change in complying, a behavior change, and an attitude change (*C-*, *B-*, or *A-Change*) constitutes the archetypes of a behavioral change. Change in itself is either of a forming, altering, or reinforcing outcome (*F-*, *A-*, or *R-Outcome*). These methodological aids can be used in a variety of settings ranging from evaluating software specifications in the early stages of systems development to studying full-fledged commercial systems.

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